BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Review of Experiment T-013, Crew/ Vehicle Disturbance - Case 630

DATE: January 16, 1968

FROM: J. Kranton
C. A. Pearse
S. L. Penn

ABSTRACT

The stated objective for Experiment T-013 by LaRC is to obtain data to refine a mathematical model of astronaut motion in zero g and of spacecraft response to that motion. It is claimed that this information is necessary in the design of control laws for CMG systems and would also be of value in the analysis of experiments which measure the effects of zero g on various phenomena.

This memorandum presents a critical review of Experiment T-013. It concludes that there is no need for the experiment in support of the ATM. This is based on the belief that the forces and moments resulting from astronaut motions can be sufficiently well determined through ground simulations and the spacecraft responses determined through analysis. To satisfy other possible purposes a far less elaborate experiment, as described herein, can be performed.

(NASA-CR-93378) REVIEW OF EXPERIMENT T-013, CREW/VEHICLE DISTURBANCE (Bellcomm, Inc.) 6 p

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MEMORANDUM FOR FILE

I. Introduction

On October 10, 1967, at Langley Research Center (LaRC), the authors attended a mid-contract review by the Martin Co. on the program definition and design development of a space experiment to determine spacecraft responses to crew motions. The presentation was followed by a lively, constructive discussion period. The experiment and Langley/Martin views are summarized below and then the authors' views and recommendations are given. Essentially, the authors do not see the need for the sophisticated experiment planned and suggest a less elaborate means for obtaining adequate information of the type desired by the sponsors.

II. Experiment Description

The objective of the experiment is to measure the effects of various crew motions on the dynamics of manned spacecraft. To do this, certain equipment would be worn by the subject astronaut and other equipment would be mounted at appropriate locations on the vehicle. The six principal items of equipment would be as follows:

1) Limb Motion Sensing System (LIMS) - An exoskeleton connecting 16 potentiometers is placed about the astronaut's joints so as to follow his limb angular motions, with 1 channel of analogue data from each potentiometer.

2) Data Acquisition System (DAS) - Mounted on the astronaut, it converts the potentiometer outputs to a digital form and transmits them via an RF link to a System Data Synthesizer (SDS - explained later).

3) Astronaut Position/Attitude System (APAS) - As yet undefined, it could consist of a 6 accelerometer inertial measurement unit, or an ultrasonic triangulation device, or a multi-camera observation system. Purpose is to determine where the astronaut is within the spacecraft and how he's oriented. Information is digitized (unless cameras are used) and fed into the SDS.

4) Digital Attitude and Rate System (DARS) - Three - axis rate gyro system plus electronic equipment for voltage to frequency conversion and angle and angular rate readout, mounted to the space vehicle wherever the vehicle responses are to be determined. Maximum sampling rate is 20 times per second (sufficient to pick up the lowest, but not necessarily all the significant, vibratory modes expected). Digital output is to the SDS.

5) Force Measuring System (FMS) - Two arrays of six load cells each, the basic element of each cell being a strain gage bridge. The arrays are mounted to the spacecraft walls, to measure applied forces and, hence, moments, and are placed approximately opposite each other, to assess free soaring effects. Digitized output goes to the SDS.

6) System Data Synthesizer (SDS) - Synchronized to the DAS, from which it gets LIMS data, it interrogates, controls, and integrates the information flow from the APAS, DARS, and FMS, and feeds the resulting output to the AAP Data Management Subsystem tape recorder or directly to the ground link TM transmitter.

Total weight of the above hardware is estimated as 100 lbs. and volume as 10 cu ft. Maximum bit rate is 6720 bits per second. The DARS gyros must be spun up from 1/2 hour before launch through the powered flight phase, requiring 30 watts. Additional power requirements are small. Performance of the experiment would require about 4.5 hours, during which other activity requiring motion would be suspended.

III. Martin/LaRC Position

Martin stated that the purpose of this experiment is to refine a mathematical model of astronaut motion in zero g and of S/C response to that motion. It is claimed that this information is necessary in the design of control laws for CMG systems and would also be of value in the analysis of experiments which measure the effects of zero g on various phenomena.

It was stated that operational equipment could not be used to determine spacecraft attitude for the experiment. This is because modification of the operational equipment to allow recording of position and rates would, probably, not be permitted. The additional interfaces required would be undesirable from the standpoint of mission success and astronaut safety. Even if it were permitted the results would: a) not be accurate enough, and b) not be applicable to the other parts of the cluster, due to the mechanical complexity of the intervehicle connections.

Martin claimed to have substantial confidence in their theoretical models of astronaut motion, but they and LaRC would like the additional assurance that the proposed tests would provide. They did not deny that ground simulation of the zero g astronaut motion would be adequate to meet their requirements for this data.

IV. Authors' Conclusions and Recommendations

Three main arguments can be advanced for performing the Crew/Vehicle Disturbance experiment in space: 1) crew motions and forcing functions need to be more precisely and reliably defined, 2) the responses of the involved spacecraft, in this case the LM/ATM and AAP cluster, to these forcing functions need to be confidently determined, and 3) the resulting data could be used for predicting the behavior of, and enabling the design of control systems for, future space vehicles having more demanding pointing requirements. It is our belief, however, that the proposed in situ measurements are not required. The first argument is weak because there is now good correlation between the mathematical model of the astronaut motions and test results in ground based simulators. Extrapolation from ground based motions to the zero-g case, can be confirmed, if necessary, by the camera scheme described below. The second argument is weak in view of our accepted ability to define the dynamics of the ATM cluster well enough to design the CMG system with considerable margin, enough to allow for much more than the expected uncertainties in the forcing functions and responses. As to the third point, this cluster has such specialized mechanical couplings that ultra precise data on its response to disturbances could not be readily extrapolated to other spacecraft.

If, despite the counter arguments given above, one still wanted to make measurements in space of crew motion forcing functions and their effects on ATM pointing, there are less sophisticated, less expensive ways of doing it than suggested by Langley/Martin. Several possibilities are discussed below. In each case mentioned, the experiment should be done both with and without the CMG system activated.

If only post flight analysis of the ATM response to crew motions is required, the current T013 equipment could be deleted and the experiment performed as follows: A set of orthogonally positioned movie cameras, calibrated and verified in pre-flight ground simulations, would be placed at appropriate locations in the workshop to record the test astronaut's motions. Attitude and attitude rate perturbations produced by these motions would be obtained from appropriate ATM instrumentation (such as the sun sensor and star tracker) and recorded and/or telemetered to the ground. The motions of other parts of the cluster in response to crew disturbances could be determined by suitably placed accelerometers, with outputs to a recorder which is synchronized with the aforementioned cameras.

If real or near real time analysis of the ATM responses were needed, then the workshop components of the T013 original equipment might have to be retained. The DARS (one of the more costly items of the present experiment hardware), however, still could be eliminated if the above ATM error signal information was available.

If the purpose of the experiment was mainly to enable in-flight adjustment of the gain settings of the CMG system by the astronauts, then, again, all the original equipment could be deleted and ATM responses determined for worst case torques only. Quantitative data to describe these and intermediate torques would not be required. In this case, the experiment should be done as early in the mission as possible.

In summary, we believe that the astronauts' motions with their resulting applied forces and moments can be sufficiently well determined through ground simulations, and the spacecraft responses through analysis, to preclude a need for the subject flight experiment in support of the ATM. For the satisfaction of other possible purposes a less elaborate version of the experiment is recommended.

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